Effects of Biota on Backscatter: Experiments with the Portable Acoustic Laboratory (PAL)

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LONG-TERM GOALS

Two long-term goals intersect in the short-term objectives of this research. As an ocean acoustician, Jones' long-term goal is to understand both the mechanisms by which benthic biota affect high-frequency (HF) scattering from sediments and their impacts on existing Navy models and systems. A better understanding of the biological causes of heterogeneity in sediment will add to the general understanding of HF acoustic interaction with the seafloor, aid in interpretation of HF seafloor imagery, and aid in the detection and identification of objects in biologically active sediments. P. Jumars is a biological oceanographer and is fully involved with this project, but is not listed as the PI because of his move to the University of Maine in 1999. Jumars' long-term goal is to identify, quantify and understand important interactions among organisms, particles (including sediments), solutes and moving fluids. The reason for this goal is to enable solutions of interesting forward and inverse problems dealing with benthic biota.

OBJECTIVES

Our common short-term objective is to provide acoustical tools for forward and inverse problems dealing with benthic biology. Namely, we seek to develop a rapidly deployable, inexpensive capability to do reductionist, mechanistic experiments concerning the effects of organisms, biogenic structures and benthic structures in general on acoustic propagation in sediments.

APPROACH

The underlying precept of this work is that one of the limitations on progress in understanding acoustic propagation, particularly at low angles of incidence with the sediment-water interface, is the lack of a laboratory facility that can realistically accommodate biological processes that may be important in affecting acoustic propagation. The primary means currently available to test ideas about biological

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effects on propagation is as projects embedded in episodic and expensive field experiments that require ship time and deployment configurations that are difficult to change "on the fly." An indoor laboratory cannot easily remove this impediment to research progress for many reasons, some of which are acoustic and some biological. Particularly at low angles with the seabed, echoes in laboratory tanks are acute problems. Another major issue in laboratory facilities is the formation or inclusion of gas bubbles in the sedimentary matrix. Yet another is the rapid degradation of "chunks" of the ecosystem brought into the laboratory to represent the natural system.

To circumvent many of these difficulties, we have developed the concept of a portable field laboratory (PAL), a set of observational tools that can "plug and play" wherever there is a source of power into and a conduit for information out from the sea. One of the assets of such an experimental facility is a known fauna and sedimentary structure, so a logical initial target is the end of the pier at an existing marine laboratory, and we have begun at the Friday Harbor Laboratories of the University of Washington. The assets are portable, however, and can be moved to another marine laboratory, or arbitrary coastal site, and this facility represents one kind of package that might be plugged into future networks of benthic marine observatories. Although our current pressure casings have limited depth capability, the same is not true of the concept.

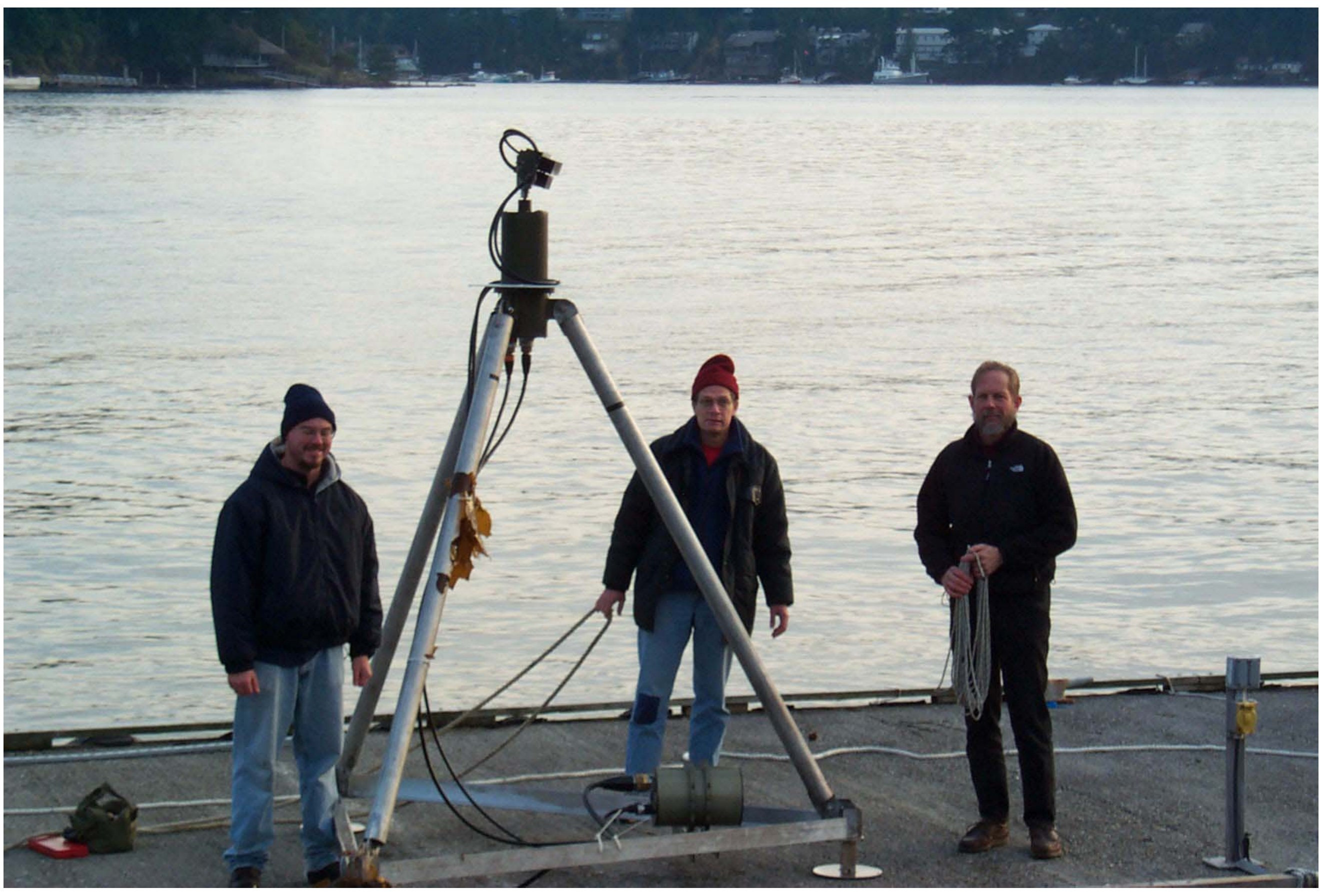

Figure 1. The PAL tripod just prior to deployment off the outer breakwater of the Friday Harbor Laboratories pier [The rotator and transducers are at the top; other electronics are in the side-mounted canister along the base. Helping with the deployment are (left to right) Shawn Shellito, Liko Self and Pete Jumars]

WORK COMPLETED

The heart of the implementation is the PAL tripod (Fig. 1), a two-frequency, radially scanning sonar system with transducers at120 and 300 kHz. It is complemented by digital stereo photogrammetry from a separate, diver-deployable frame. We have much less experience with these two acoustic frequencies than with 40kHz, but the experience that we do have suggests that it is difficult to separate backscatter from the bottom from backscatter caused by animals in the water near the bottom. To field test the system and attempt to separate benthic signals from water-column volume reverberation, we therefore deployed PAL together with a TAPS-6 (Tracor Acoustic Profiling System, BAE SYSTEMS, Inc.).

Our first task has been to get the PAL system built and running. We have been seriously delayed by three problems, now overcome. PAL appeared to suffer from pressure-sensitive cable shorts. This diagnosis proved false, and it was instead a faulty computer card in the internal electronics. PAL now takes data continuously in both 300- and 120-kHz modes, and the second problem — electrical noise — has been controlled though not eliminated by internal shielding and post-processing the data with matched filters. The electrical noise has been isolated to the motor that turns the transducer head. However, for the initial experiments in which PAL and TAPS are run simultaneously, the motor is not used and electrical noise problems have less impact on data quality. The third problem was an intermittent connection in one cable section on the charging circuit of TAPS-6, and this cable has been replaced.

We have collected PAL and TAPS-6 data jointly from mid June through mid September, with some gaps. The data record is long enough to allow both statistical and phase-based approaches to separating benthic and planktonic signals, and those analyses are now under way.

RESULTS

Analyses are not yet sufficiently advanced to draw conclusions about the feasibility of separating benthic and near-bed planktonic signals, but the data quality is satisfactory (Fig. 2).

IMPACT/APPLICATION

We anticipate that this kind of portable field laboratory will be useful for answering many specific questions about potential biological effects on backscatter. For example, in the benign setting of a field laboratory, it is feasible to deploy mine-like objects and monitor how their acoustic signatures change as organisms foul their exposed surfaces and bioturbation and perhaps geochemical processes alter their acoustic coupling with overlying water and underlying sediments.

RELATED PROJECTS

This proposed work is part of a more general long-term effort on our parts to develop means of detecting benthic organisms and their activities over unprecedented scales (notably over large areas and short times compared to any sampling methodology used previously) and to determine their impacts on acoustic propagation. It was fueled by two empirical studies suggesting biological effects on backscatter (Jumars *et al.* 1996; Briggs and Richardson 1997) and a theoretical one showing that temporal decorrelation in backscatter at some sites is consistent with a simple model of bioturbation (Jones and Jackson 1997). We followed up with experimental manipulations to test that hypothesis (Self *et al.*, in review). SAX99 extended these efforts to sediments with greater sound-speed contrasts (with sound speed in overlying seawater; Richardson *et al.* 2001 and in preparation). This work on biological and biogenic effects

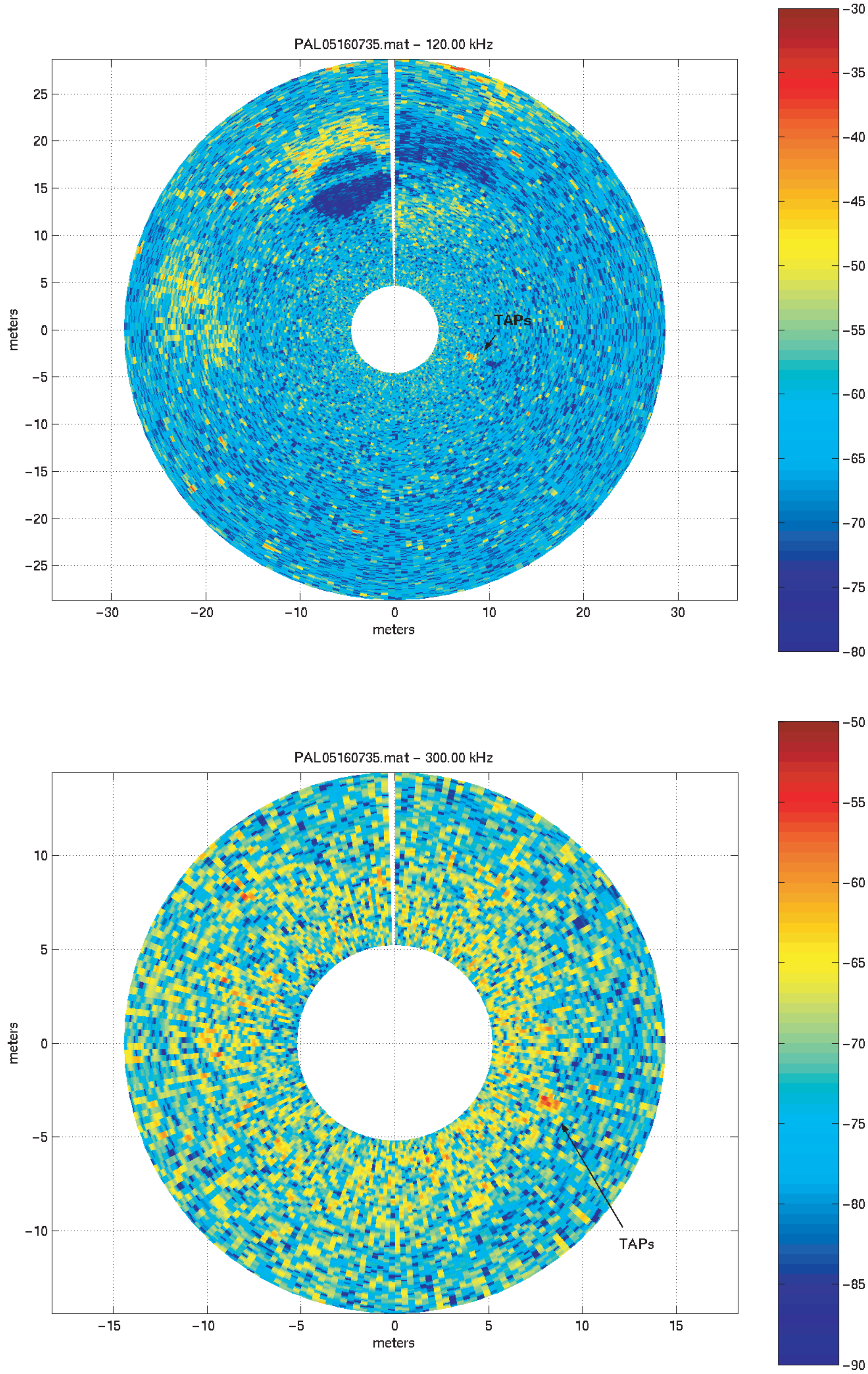

Figure 2. Sample data from PAL at both 120 and 300 kHz [Shown are two false-color sonar circles taken during the joint observations with TAPS-6. In both scans, the TAPS-6 in its frame (arrows) is evident as a region of elevated backscatter. The 120-kHz scan extends further radially and also resolves low-backscatter patches (blue) that are depressions made by scour about the anchor and anchor chain (yellow line of pixels curving in from the left) for the breakwater.]

has been done in collaboration with Richardson and Briggs of NRL Stennis. Their measurements for Orcas were embedded in Self *et al.* (2001), and we have mutually agreed that our manipulations in SAX will be embedded in a broader manuscript on SAX99 manipulations that they will lead. Briggs has also participated in the diving tasks of PAL during his 2001 stay in Washington State and shares our interest in stereophotogrammetry. We view these long-term efforts to be complementary and well integrated.

This work is a collaboration between Chris Jones of the Applied Physics Laboratory, University of Washington, and Pete Jumars of the University of Maine. The project was initiated when Pete Jumars was at the University of Washington, and the Director of the School of Oceanography, Bruce Frost, has become the titular Principal Investigator of the University of Washington component while Pete Jumars is the PI of the University of Maine component. The titles and texts of these two grants (N00014-00-1-0034 and -0035) are identical.

Under separate funding, Pete Jumars at the University of Maine is also working with the related phenomenon of emergence by seabed fauna that may influence both surface microtopography and volume heterogeneity. This complementary grant is entitled “Shallow Scattering Layer (SSL): Emergence Behaviors of Coastal Macrofauna” (N00014-00-1-0662). It is also an informal collaboration with Van Holiday of BAE SYSTEMS, Inc., with whom we are finishing a manuscript on emergence behaviors (Kringel *et al.,* in manuscript). Van Holliday has decided that the data warrant development of a more geometrically accurate (than the bent cylinder) model of the mysid body for purposes of inversion.

REFERENCES

Briggs, K.B., and M.D. Richardson. 1997. Small-scale fluctuations in acoustic and physical properties in surficial carbonate sediments and their relationship to bioturbation. *Geo-Marine Lett,* **17:** 306-315.

Jones, C., and D. Jackson. 1997. Temporal correlation of backscatter due to bioturbation in marine sediments. Saclantcen Conference Proceedings CP-45: High-Frequency Acoustics in Shallow Water, Lerici, Italy, July, 1997.

Jumars, P.A., D.R. Jackson, T.F. Gross and C. Sherwood. 1996. Acoustic remote sensing of benthic activity: A statistical approach. *Limnol. Oceanogr.* **41:** 1220-1241.

Kringel, K., P.A. Jumars and D.V. Holliday. High-frequency acoustic assessment of nocturnal vertical migration from the seabed: the shallow scattering layer, in manuscript being prepared for submission to *Limnol. Oceanogr.*

Richardson, M.D., K.B. Briggs, L. Dale Bibee, P. A. Jumars and others. 2001. Overview of SAX99: Environmental considerations. *IEEE J. Ocean Eng.* **26:** 26-53,

Self, R.F.L. P. A’Hearn, P. A. Jumars, D. R. Jackson, M. D. Richardson and K. B. Briggs. 2001.· Effects of macrofauna on acoustic backscatter from the seabed: field manipulations in West Sound, Orcas Island, WA, USA, *J. Mar. Res.,* in press.